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Materials Report 79-C

HIGH-BUILD VINYL COATINGS FOR USE ON THE CATHODICALLY PROTECTED BOTTOMS OF SHIPS

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6 HIGH-BUILD VINYL COATINGS FOR USE ON
THE CATHODICALLY PROTECTED BOTTOMS OF SHIPS

by

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ABSTRACT

A number of high-build vinyl anti-fouling shipbottom coatings, formulated both for airless hot spray and conventional spray application, have been evaluated in the laboratory and on service vessels. The main objective of the investigation was to find an underwater coating system with equivalent performance to the Maritime Forces' specified vinyl system, but one requiring fewer coats of paint and therefore lower labour costs and a shorter application time.

In this evaluation, the formulations for hot spray and airless hot-spray application proved better than those formulated for high-build application with conventional spray equipment. A four-coat system consisting of one coat of vinyl wash primer applied by conventional spray, followed by a high-build aluminum-vinyl primer, an intermediate high-build vinyl-aluminum anti-corrosive coat, and a coat of 1-GP-123 vinyl cuprous oxide anti-fouling, all applied by hot spray, achieved the required ten mil minimum total thickness and, on the basis of the laboratory and ship trial performance, can be considered for general use.

INTRODUCTION

The standard aluminum vinyl system* has performed excellently on the cathodically protected bottoms of ships of the Canadian Armed Forces.[1] Its main disadvantage has been the low dry-film thickness achieved per coat of paint applied, about one mil for the anti-corrosive and two to two and one-half mils for the anti-fouling. With increasing labour costs, it is desirable to get a greater thickness per coat in order to prevent the cost of painting a ship's bottom from accelerating drastically. This report describes work done in formulating and evaluating vinyl bottom paints which can be applied in greater dry-film thickness per coat.

PAINT FORMULATION

The formulations used to produce high-build vinyl paints for evaluation are given in Tables I and II. The high-build anti-corrosives were formulated by the author. The experimental anti-foulings were modifications of formulations by Ginsberg and Stevens.[2]

The approach to the formulation of the high-build anti-corrosive was based on the assumption that any such coating would adhere best when used over a vinyl wash metal pretreatment primer (CGSB 1-GP-121), the latter being applied by conventional spray. Two basic types of anti-corrosive high-build coatings were formulated: a prime-coat for maximum adhesion to the vinyl wash primer, and a second coat for maximum thickness buildup.

The primer coatings (suffix 1 in identification code, see Table I), were formulated with the vinyl resins VAGH, VAGD or combinations of these two resins. These resins are copolymers of vinyl chloride, vinyl acetate and vinyl alcohol. The hydroxyl groups of the vinyl alcohol enhance the adhesion to wash primer because the latter also contains hydroxyl groups. The resin VAGD has a lower molecular weight and yields a resin solution of lower viscosity. VAGH films are stronger, but thinner than the VAGD type.

*1 coat CGSB 1-GP-121 vinyl wash primer

5 mils (min) (normally 4-5 coats) CGSB 1-GP-122 Type 3 vinyl aluminum anti-corrosive

5 mils (min) (normally 2 coats) CGSB 1-GP-123 cuprous oxide vinyl anti-fouling.

The second-coat anti-corrosives formulated for the greatest thickness, (suffix 2 in identification code), were made with vinyl resins VYHH, VYLF or both. These resins, which are copolymers of vinyl chloride and vinyl acetate, are similar, except that the VYLF has the lower molecular weight. Since these resins lack hydroxyl groups, they do not adhere to wash primer as well as coatings made from the VAGH or VAGD type. However, the VYHH and VYLF resins have a lower viscosity for a given concentration, and therefore can be formulated to yield films of greater dry thickness.

If one tries to apply thicker than normal coats of paint with conventional air atomization equipment, two main problems arise. The first difficulty is with delayed solvent evaporation, which can cause porosity, and poor adhesion and cohesion. The delayed evaporation results from too rapid surface drying or "skinning". This "skinning" problem can be minimized by the substitution of part of the solvent mix with a higher boiling fraction. In the case of the vinyls, part of the MIBK and toluene solvents can be replaced with a higher boiling fraction such as cellosolve acetate or cyclohexanone.

The other main problem with applying thicker coats of paints which have been formulated for conventional sprays, is their tendency to "run" and "sag", which wastes paint, increases solvent retention problems, is unsightly, and in the case of hull bottom paints, causes extra frictional drag. Increasing the viscosity of the paint reduces these problems.

TABLE I

Formulations for Vinyl Anti-corrosive Paint

Component	Percent by Weight						
	1-GP-122 Type 3	AH-1	CH-1	EC-1	BH-2	DH-2	FC-2
Aluminum Powder	9.05	10.20	10.75	7.42	19.43	20.62	6.70
Bentine 27		.92	.97		.79	.84	
Cabosil				4.15			3.75
VAGH resin	17.90	9.25		14.60			
VAGD "		9.25	19.43				
VYHH "					11.06		
VYLF "					11.06	23.41	22.85
Dioctyl phthalate	1.85	1.99	2.09	1.50	2.23	2.34	1.35
Butyl acetate			9.44			7.49	
Cellosolve acetate			36.49	50.60		28.85	45.72
Methyl isobutyl Ketone	35.60	33.99	6.96	7.22	31.65	5.52	6.52
Toluene	35.60	30.39	13.41	7.95	20.30	10.58	7.18
Xylene				5.10			4.61
Cyclohexanone		3.58			3.16		
Epichlorohydrin		.13	.14		.10	.11	
Methanol*		.30	.32		.22	.24	
V.M&P Naphtha				1.46			1.32

*Methanol contained about 5% water

TABLE II

Formulations for Vinyl Anti-fouling Paints

Component	Percent by Weight			
	1-GP-123a	G	H	I
Bentone 27	.44			
Cuprous oxide	70.28	65.30		43.87
Kaolin			1.79	
Titanium dioxide			1.19	
Carbon black			6.43	
Tributyl tin fluoride			11.14	9.50
Cabosil		1.39	1.23	1.87
VYHH resin	2.68	2.49	4.68	3.35
WW rosin	10.50	9.75	18.64	13.10
Dioctyl phthalate	2.44	2.27	4.33	3.05
Cellosolve acetate		13.15	29.89	17.67
Methyl isobutyl ketone	8.05	1.88	8.07	2.53
Toluene	5.61	2.07	7.09	2.78
Xylene		1.32	4.67	1.77
V M and P Naphtha		.38	.85	.51

To make a viscous paint more readily sprayable, (other than by adding more solvent), its viscosity can be temporarily reduced by heating it (hot spray), or by adding a thixotropic agent such as finely divided silica ("Cabosil"). The heated or thixotropic paints gel very quickly on reaching the surface being coated and therefore the tendency for sagging or running is much reduced.

Test Paint Application

In both the laboratory and ship trials, all the test coatings were applied to a thickness just short of sagging on vertical surfaces. Atomizing pressure for both the conventional and hot spray was 50-85 psig with a pot pressure of 15-20 psig. For the hot spray, the paint was maintained at about 65°C at the outlet of the heat exchanger. In the laboratory tests, panel-to-gun distances were maintained at 6 inches. For the ship application, gun distance was 12 to 18 inches.

The average dry-film thicknesses achieved in the laboratory and ship trials are listed in Tables III, IV and V.

Evaluation Procedures

In the laboratory, the high build systems were evaluated using the "Resistance to cathodic protection requirement" of the standard "DREP Laboratory Procedure for Qualifying Ship Bottom Coatings".[3] Under this requirement, the paint system qualifies if there is no loss of adhesion, other than blistering, within ¼ inch of the scribe marks after immersion for 100 days in sea water at a cathodic potential of -1.0 volt vs Ag/AgCℓ.

In the above evaluation the anti-corrosive paint is part of a complete system including an anti-fouling paint. While the actual anti-fouling properties have to be evaluated in other ways, it is useful to have the anti-fouling paint included so that any tendencies for intercoat blistering or loss of adhesion between it and the anti-corrosive are shown up.

TABLE III

AVERAGE THICKNESS PER COAT OF EXPERIMENTAL HIGH-BUILD AND STANDARD VINYL BOTTOM COATINGS

Class	Formulation	Method of Applic.	Av Dry Film Thickness Per Coat (mils)
Anti-Corrosives	1GP122 Type 3 Aluminum vinyl Standard Anticorrosive	Conv.	1.0
	AH1	Hot	2.4
	CH1	Hot	2.8
	EC1	Conv	1.7
	BH2	Hot	4.1
	DH2	Hot	5
	FC2	Conv	3.2
Anti-Foulings	1GP123a Cuprous oxide standard Antifouling	Conv	2.3
	1GP123a Cuprous oxide standard Antifouling (unthinned)	Hot	5.0
	G(Cuprous oxide)	Conv	5.0
	H (TBTF-Black)	Conv	4.0
	I (TBTF-Cu_2O)	Conv	5.9

TABLE IV

PERFORMANCE OF HIGH-BUILD VINYL COATINGS IN LABORATORY TRIALS

Type of Trial	Coating System	Method of Applic.	Av Dry Film Thickness (Mils)	Resist* Under Cathodic Protect (100 Days)	Remarks
Lab	Vinyl Wash Primer (1-GP-121)	Conv	0.3	Passed	
	AH1	Hot	2.1		
	BH2	Hot	4.1		
	1-GP-123a Vinyl A/F	Conv	2.3		
Lab	Vinyl Wash Primer (1-GP-121)	Conv	0.3	Passed	One panel showed one blister within ¼" of score mark
	AH1	Hot	2.7		
	DH2	Hot	5.6		
	1-GP-123a Vinyl A/F	Hot	5.0		
Lab	Vinyl Wash Primer (1-GP-121)	Conv		Failed	Blisters in score area up to 3/8 inch in diameter. (One panel out of 5 not blistered.) CH1 maintained adhesion but lost cohesion. Water oozed from CH1 when pressure applied.
	CH1	Hot	2.7		
	DH2	Hot	4.5		
	1-GP-123a Vinyl A/F	Conv			

TABLE IV - cont'd

Type of Trial	Coating System	Method of Applic.	Av Dry Film Thickness (Mils)	Resist* Under Cathodic Protect (100 Days)	Remarks
Lab	Vinyl Wash Primer (1-GP-121)	Conv	0.3	Passed	Water absorption and loss of cohesion in CH1 layer
	CH1	Hot	3.0		
	DH2	Hot	5.6		
	1-GP-123a Vinyl A/F	Conv	2.3		
Lab	Vinyl Wash Primer (1-GP-121)	Conv	0.3	Failed	Intercoat blistering between FC2 anti-corrosive and G anti-fouling - over most of panel
	EC1	Conv	1.7		
	FC2	Conv	3.2		
	G	Conv	5.0		
Lab	Vinyl Wash Primer (1-GP-121)	Conv		Passed	Although system qualified at 100 days, after 6 months immersion, 'H' anti-fouling could easily be peeled from the anti-corrosive layer.
	1-GP-122 Type 3 Al Vinyl (2 coats)	Conv			
	H	Conv	4.0		
Lab	Vinyl Wash Primer (1-GP-121)	Conv		Passed	
	1-GP-122 Type 3 Al Vinyl (2 coats)	Conv			
	I	Conv	5.9		

* To pass "Resistance Under Cathodic Protection Requirement" there must not be any loss of adhesion except that blisters are permitted within ¼ inch of the score.

TABLE V

PERFORMANCE OF HIGH BUILD VINYL ANTI-CORROSIVE COATINGS IN SERVICE TRIALS

Type of Trial	Coating	Method of Application	Av Dry Film Thickness (Mils)	Remarks
Tug	Vinyl Wash Primer (1-GP-121)	Conv	6	After 26 months afloat both conventional and experimental systems remained in very good condition. Demarcation line between experimental and standard systems could not be seen.
	AH1	Hot		
	BH2	Hot		
	1-GP-123a Vinyl A/F	Conv		
Ship	Vinyl Wash Primer (1-GP-121)	Conv	6	After 38 months afloat the bottom paint was in excellent condition over most of the area, but there were a few patches of blisters and copper conversion. Conventional and experimental quarters were about equal.
	1-GP-122 Type 3 (2 coats)	Conv		
	BH2*	Hot		
	1-GP-123a Vinyl A/F	Conv		

* Two coats applied because inadequacy of heating of airless hot spray unit necessitated use of thinned material to make it sprayable.

RESULTS

Anti-Corrosive Paints

Laboratory Trials

As can be seen in Table IV, of the three first-coat aluminum primers (Suffix - 1) formulated for adhesion to wash primer, only the AH1 formula for hot spray, at an average thickness of 2.4 mils, consistently passed the laboratory evaluation. The CH1 formulation failed the cathodic protection resistance requirement in one of two tests, and also suffered cohesion failure. The EC1 formulation failed the cathodic protection resistance requirement.

In the laboratory trials, all of the high-build second coat anti-corrosives appeared to perform satisfactorily. However, only the BH2 formula has been service tested.

Service Trials

Table V gives the results of the service trials. The AH1 first coat high-build anti-corrosive performed very well in the 26 month tug trial. In the 38 month ship trial, a coat of the conventional 1-GP-122 Type 3 aluminum pigmented vinyl anti-corrosive was used as the first coat because of non-availability of the AH1 material. In both cases the BH2 high-build second coat formulation worked well, with the combined anti-corrosive systems giving equal performance to the conventional multi-coat 1-GP-122 Type 3 system.

Anti-Fouling Paints

Of the three experimental anti-fouling formulations, the "H" material with the TBTF (tributyltin fluoride) toxin can be rejected because it did not achieve the minimum 5 mils thickness in one coat and because it did not adhere well to the anti-corrosive. The 'G' anti-fouling formulation failed because of the intercoat blistering from the FC2 anti-corrosive.

The "I" formulation with its combined cuprous-oxide - TBTF toxin, maintained its integrity and adhesion, and could be considered for a ship trial after its anti-fouling capability has been determined.

At the moment, the standard unthinned 1-GP-123a vinyl anti-fouling with its cuprous oxide toxin, appears to be the most practical high-build

anti-fouling paint for general use. It has the advantage that it is already in the supply system and in the unthinned condition can be sprayed with air-less hot spray at about 5 mils per coat. While the anti-fouling properties of the hot-applied material have not yet been confirmed, it is reasonable to assume that they will not differ significantly from those obtained at present with the same formula thinned and applied by conventional spray.

CONCLUSIONS

1. The experimental high-build aluminum vinyl anti-corrosive system consisting of 1 coat of each of formulae AH1 and BH2, when applied by the hot spray technique, easily achieves the specified minimum total underwater hull anti-corrosive thickness of 5 mils. In both laboratory and ship trials this system has been shown to be equivalent in performance to 5 mils of the multi-coat standard aluminum-vinyl anti-corrosive (1-GP-122 Type 3).

2. With the hot spray technique, the unthinned standard 1-GP-123a vinyl cuprous oxide anti-fouling paint can be applied in one coat to achieve the 5 mil minimum thickness specified for the vinyl anti-fouling for ship bottoms.

3. Considerable savings could be achieved by the use of high-build vinyl bottom coatings applied by hot spray. The total number of coats for a new bottom system would be reduced from six or seven (in addition to wash primer) for the conventional coatings and spraying techniques, to three coats with the high-build vinyls applied by hot spray. Painting time for a ship's bottom could be reduced to a minimum of three days from five.

RECOMMENDATION

On the basis of the above trials, a recommended high-build system would be:

1 coat of vinyl wash primer (1-GP-121) 1 coat of AH1 aluminum vinyl A/C first coat 1 coat of BH2 aluminum vinyl A/C	5 mil minimum total thickness
1 coat of unthinned cuprous oxide vinyl A/F (1-GP-123a)	5 mil minimum thickness

The wash primer coat would be applied by conventional spray, the other three coats by hot spray.

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